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THE APPLICATIONS OF SCIENCE[1]

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THIS assemblage needs no definition of science; nevertheless for our present purpose I shall characterize science as the disclosure of the facts of nature, and the orderly study of such facts with a view to the establishment of their interdependent relations.

If we ask why we should concern ourselves with the examination of the facts of nature or with the interdependences which seem to connect them in the relation of cause and effect, we may find at least two fundamental reasons and these are:

1. As a response to the innate curiosity with which we are endowed regarding the universe, its constitution, phenomena and laws of evolution: or otherwise in response to the joy of achievement and conquest which we feel in being able to enter some little way into the *arcana* of nature.

2. In order that the phenomena disclosed or the laws established may be applied in the service of humanity.

It is to this second purpose that I am to specially direct your attention for a few moments.

In nature and by themselves all facts are of equal importance or value. Or, rather, the concept of value or importance does not and can not attach to a fact or a law of nature as such. Rather, the facts and laws of nature are beyond value and do not admit of comparison as to relative importance. It it only as they come to be applied that they take on relative value or significance. This value or significance is therefore something wholly extraneous to the fact or law itself, something contingent on the particular circumstances which surround its application to the demands of civilization.

Again it will perhaps be admitted, as a broad generalization, that until the facts of science have reached the status of application in the service of humanity, they have not reached their widest plane of significance, nor have they justified to the full the human energy which may have been expended in their disclosure. The progressive widening of the scope and significance of a fact of science may be noted in three stages.

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[1] An address presented in a symposium on "Coordination and Cooperation in Research and in Applications of Science," held during the meeting of the Pacific Division of the American Association for the Advancement of Science at Leland Stanford Junior University, April 5 to 7, 1917.

1. Its discovery or establishment by the worker in some field of science. So long as it does not go further, this fact is known only to its discoverer and to the omniscient intelligence pervading nature. It gives the discoverer a thrill of the joy of conquest; or it may awaken feelings of awe or wonder at the sublime harmonies of nature.

These, however, are purely subjective. They relate to the discoverer alone. The significance of the fact has not yet passed beyond the boundaries of his being.

2. We may next suppose that the fact is spread abroad and made a part of the common stock of scientific knowledge. Its significance now becomes greater. It helps all workers in science to better understand the secrets of the universe; it may help humanity broadly toward a higher and nobler appreciation of the works of nature. The significance of the scientific fact is thus enormously widened and deepened. It has not yet, however, passed beyond the domain of intellectual or esthetic appreciation.

3. If now in the third stage we suppose that some application of the observed fact or established law may be made which will aid in curing disease, in giving us new comforts in the home, in rendering life and its activities safer or fuller, we have the realization of the final stage in the widening significance and value of this fact of science.

We may perhaps imagine Oersted's intellectual gratification in developing a coherent formulation of the laws governing the mutual relations of a magnet and an electric current.

We may likewise imagine the intellectual satisfaction with which the scientific world of his day received this formulation. The significance of Oersted's work, had it remained bounded by these results, however, would fall far short of the significance in the world of to-day, of the electric motor, with its countless points of relation to our comfort, safety, pleasure, and appreciation of the content of life.

We may imagine the spiritual exaltation with which Crookes about 1880 glimpsed his so-called fourth state of matter. Those of us above forty years of age will probably remember the awed and exalted state of mind with which we entered into some knowledge of his work.

However, had Crookes and others working in the same and allied fields gone no further, and if no application in the service of humanity had been made of the early observations of Crookes, Roentgen, Becquerel, the Curies and others, then would the influence on the human race or the significance to it of these scientific discoveries have been small indeed compared with the present significance of the cathode ray and the various radioactive substances, a significance which seems likely to grow in the future in ways and to an extent of which we can gain no present vision.

Illustrations might be multiplied beyond measure, but it is unnecessary for our purpose. It will, presumably, be admitted that until a fact of science has realized some useful application in the arts of life or in the service of humanity, it has not reached its highest and widest significance. Short of such application it stands indeed as a conquest gained in the struggle with nature, it stands as a fact of mental achievement, it stands as a fact in relation to the intellectual life of the discoverer and perhaps of the intellectual lives of thinking men and women the world over; but it has not yet reached the status where it may be counted as a factor in the material or outward content of life, and to this extent at least it has failed of realizing the full measure of its significance to humanity.

I should perhaps note at this point that not all facts of science seem equally applicable to the immediate service of humanity—at least in outward and material ways. Indeed many of the facts of science seem hopelessly removed from the opportunity of application to the arts of life; for example, portions of advanced pure mathematics and much of astronomical research. This does not imply that for this reason such fields of science are the less worthy of intensive cultivation than those where the opportunities of application seem more probable. In the first place no one may dare predict the future significance of any fact of science, no matter how remote it may seem from useful relation to the needs of humanity at the present moment. It is the glory of the worker in pure science that he is not concerned with the question of application as such; *that* he leaves to others and to the future. He is endeavoring simply to uncover some portion of God's truth and to place it on deposit in the great storehouse of scientific knowledge, whence it may haply be drawn in the fullness of time to serve some purpose now far below the horizon of our thought.

All this, however, does not affect the truth of the broad thesis that when such facts of science shall have been drawn out of the storehouse and applied in the service of humanity, then will they reach the full measure of their potential significance to humanity and then will they have fully justified the energy expended in their pursuit and disclosure.

And so to close this phase of the discussion I repeat that a fact of science until it has been applied in the service of humanity is potential in its relation, at least to our outward and material life. When it has reached the stage of useful application, this potential relation or significance has been transformed into an actual and real significance. It has then taken its place as a factor in the life of the human race.

The problem of the application of science may be phrased as the problem of bridging the gap between science on the one hand and the needs of humanity on the other.

We find that the problem thus broadly stated divides under perhaps two typical forms or types:

1. Given a fact of science, what are its useful applications?

2. Given a demand or need presented by the arts of life (using this term in its broadest sense), what facts of science may serve as significant factors in meeting the demand or in supplying the need?

The history of science with reference to its application in the arts of life shows abundant illustration of both types of problem, while naturally many cases are of an intermediate or mixed type.

In particular the second type presents two variations: (*a*) Where the needed facts of science have presumably been already developed and are stored away ready for use on demand, and the problem becomes simply that of finding or identifying them among the vast store open for inspection. (*b*) Where the needed facts of science have not been developed and the problem becomes that of organizing and directing an investigation in science along specific lines and with reference to the solution of a specific practical problem.

The two factors which are most likely to be of significance in the first typical problem are:

(*a*) Imagination or vision.

(*b*) Wide acquaintance with the needs represented by the arts of life, especially when expressed in terms of their scientific factors or elements.

For the problems under type two the factors which are most likely to be of significance are:

(*a*) Wide acquaintance with the results of scientific research along lines likely to stand in a fruitful relation to the practical problem in hand.

(*b*) Such degree of vision or imagination as will aid in identifying such scientific facts or relations as are likely to prove of special help in connection with the particular problem in hand.

(*c*) Resourcefulness, energy, persistence, patience, capacity for analysis, synthesis, deductive logic, and all the other qualities of mind and character which we associate with the successful worker in special fields of science.

With regard to these typical problems a few observations.

The first problem may arise in connection with the discoverer of the fact or relation. The fact itself having been established, the question of its possible application may arise. It is an interesting thought that, purely as a matter of probability, the chances are, I believe, overwhelmingly in favor of the existence of some, perhaps many, direct and useful applications in the arts of life, even in the stage of advancement of the present day. It is a further thought of the deepest interest that thus far, at least, we have developed no scientific method for establishing the connection between the facts of science and their potential applications. As a broad fact or at least as a high probability we may say that the application doubtless exists: how may we discover it.

To our present contracted view it seems to call for what I often like to term the all-seeing eye; an intellectual eye is implied, of course. If we may postulate such an eye, and this is equivalent to postulating omniscience, we may picture this eye roving over the field of human endeavor with special reference to what I have termed the arts of life, and unerringly resting on those arts, or on the problems connected with such arts, as would offer a field for the helpful application of the fact of science in question. But, alas, we have not attained to this stage of evolution. Rather we are looking through a narrow aperture with clouded vision and can only make out imperfectly here and there uncertain features of the landscape which lies before us. To leave the figure of speech we need some means of approaching an orderly study of method, whereby relations between facts of science and problems of life may be more readily correlated.

With vision or imagination and some acquaintance with the problems presented by the arts of life, applications may be found, but the whole process is, for the most part, without method and depends on a fortuitous combination of happy circumstances rather than on scientific procedure. And so we conclude that in perhaps the most important of all possible scientific problems, that of the application of the results of scientific work to the arts of life, we are wholly without a scientific method. Why should there not be a kind of superscience, a science which should have for its purpose the correlation of the immediate results of scientific work with the arts of life and thus the realization, at the earliest moment and in the fullest degree, of the potential value of the results of scientific work?

With regard to the second problem the condition is much the same as with the first. The demand here is for some fact of science applicable to a specific problem arising in connection with the arts of life. Here again the interesting thought occurs that in all human probability there now exists stored away and perhaps lost sight of in the storehouse of science, some fact, observation or correlation which will furnish the solution desired, or at least serve as an important factor in the prosecution of the problem. This is a reflection over which we may well ponder, restive at the thought that beyond all human probability there are now stored away in the annals of science facts of observation or generalizations in the form of laws which would have fundamentally important applications to specific problems now pressing for solution. These problems are before us and engage our attention. The arts of life urge speedy results. The necessary scientific work has perhaps all been done and the results are stored away beyond the scope of our immediate vision. How deplorable the situation. Why have we pursued science with such zeal, and taken no pains to provide for the better utilization of the facts when once disclosed?

The situation results further in the most serious economic waste. It results in the rethreshing of old straw, in the rediscovery and recataloguing of the facts of science when once should have been enough.

Is there not some way, when once a fact of science has been disclosed, of so cataloguing it and placing it on exhibit that it will not be necessary to rediscover the same fact a few years later, when there may arise some problem in the solution of which it must play a significant part?

It will be said, and with truth, that oftentimes the rethreshing of the old straw and the rediscovery of the already known fact arise from indolence or from negligence to search the records for such material as may be found. This is often the case. It is true, on the other hand, however, that there is urgent need for improvement in our system of keeping the record, and also that the scientist best adapted perhaps to work out the practical problem is not always the best adapted to make a search of the record for the facts of science which may be of aid in dealing with the problem.

What seems to be needed is the development of a science of the use of science—a science whose purpose shall be the saving of waste energy in searching for scientific facts or principles applicable to specific problems, and likewise the development of economic and effective methods in seeking for useful applications of the elements of scientific knowledge.

The practical question immediately arises, as to the possibility of realizing anything effective in the way of such a science. What should be its factors, what its methods of procedure?

The answer to these questions requires more wisdom than I can command, but some few items, at least, are fairly obvious.

Quite aside then from the question of practicability, let us seek some of the more obvious elements of such a science. Among these the following may be noted:

1. A clearing-house or classified storehouse for scientific knowledge.
2. A clearing-house or classified storehouse for the diverse needs of humanity.
3. A staff of scientific workers whose duty it shall be to gather, analyze and prepare scientific data in various ways with reference to the development of points of application with the needs of humanity.
4. A staff of workers whose duty it shall be to gather, analyze and prepare in various ways data relating to the needs of humanity and with special reference to the development of relationships with the underlying scientific facts.
5. A staff of scientists whose duty it shall be to work with the material prepared by these corps of workers and whose energies will be directed toward the development of relationships between these two classes of materials, the facts of science on the one hand and the needs of humanity on the other.

The mere statement of this schedule of fundamental elements of such a science will bring a smile, perhaps, by reason of its impracticability, at least at the present time and in any large sense. The field seems too great to attempt its compass by any corps of workers of which we can readily conceive. When we consider, on the one hand, the existing facts of science, together with the generalizations and principles or laws which are intended to correlate them, and on the other the needs of humanity as expressed in matters to which science might stand in a helpful relation—when we picture for a moment the vast expanse of this field, the millions of items of which some cognizance must needs be taken, and also the astonishing rate at which the store is accumulating, the task seems quite hopeless in any extended or comprehensive sense.

Leibnitz, I believe, has been indicated as the last great scientist whose mind could be said to have compassed practically the then existing store of scientific learning. Regardless of the degree of accuracy with which such a statement can be made, it is very sure that no mind of the present day can do more than hold in view the content of a very small corner of the constantly widening field of scientific activity. And as the years go by the condition becomes ever more aggravated in this respect. We are continuously adding to the scope and variety of our store, its extent both in number and diversity of character becomes daily more bewildering, and in corresponding degree the task of developing an effective science of the use of science becomes seemingly ever more and more hopeless.

Confronted with such a condition, what should be our attitude? Should we continue to do nothing and allow the content of the body of science to increase without regard to the question of its application, or should we make some attempt to improve the existing condition. Is it not worth our while to attempt at least to take the measure of the undertaking in certain limited areas of the field, or to do some little even if a comprehensive treatment lies beyond our capacity?

I believe that this is our clear duty. Because we can not do everything which an ideal treatment might indicate, it does not follow that we should not do what we may. It will mean a distinct effort along measurably new lines. It will imply assemblage, analysis, selection, synthesis in various ways, classification, coordination and the development of ways and means of detecting and setting forth what the mathematician might term systems of point correspondences between the two classes of material, scientific facts on the one side, human needs on the other. May we not anticipate that one of the triumphs of the twentieth century will be the making of some effective progress toward the establishment and development of a science of the use of science.